P-132: Real-Time Simulation Software for Electro-Optical Calculation of LC Cells

Anatoli Murauski, Svetlana Serdechnaya, and Hoi-Sing Kwok,
Center for Display Research, Hong Kong University of Science and Technology,
Clear Water Bay, Hong Kong

Abstract

New principal for LCD modeling is proposed. We developed a real-time simulation software based on fast algorithms for solving differential equation. Rapid calculation of LC structure allows the change of electrooptical response to be seen immediately after changing any parameters of liquid crystal or cell configuration. The software is useful for fitting the measured parameters related to LC materials and device and for device optimization. To demonstrate the power of this software, transmittance voltage dependences were simulated and relaxation time optimizations were carried out. Our rapid algorithm can be used for dynamic driving simulations and overdrive optimization as well.

1. Introduction

At this moment there exist many powerful software packages for modeling liquid crystal devices and their electrooptical effects [1]. The most commonly used ones among them are DIMOS (Display Modeling System) [2], LCD Master (Modeling and Evaluation Software System for LCD Designers), Mouse-LCD and LCD-DESIGN [3,4].

These programs have common organization and include two independent parts: one for profile deformation calculation and other for optics calculation. Profile deformation calculation usually requires much time. That is why all programs have two parts. It makes the operation of the software inconvenient. The change of any parameter of liquid crystal requires total recalculation of LC profile deformation. For fundamental investigation of electrooptical effects, how fast the program works, is not important. But for engineering works when it is necessary to calculate the influence of some individual parameter of LC device on the electrooptical response, the calculation time plays much more important role. Ideally one should be able to see the change in real time in the simulation. The time of software calculation is even more critical for fitting procedure to determine values of LC and device parameters. We propose and demonstrate here a software that can give simulation results in real time, Such software is extremely valuable in device optimization if the number of parameters become large.

2. Methodology

Any calculations of LC device include two steps. First, the LC director deformation profiles must be found for any applied voltages. Second step is calculation of optical properties for obtained configurations. We concentrate our efforts to increase the speed of the first calculation. The usual relaxation method is not suitable for real time calculation software. Relaxation procedure has exponential dependence for changing angle of liquid crystal with time. It means that precise values for stable state distribution can be received for infinite time only. In reality the calculation is stopped when change in system decrease and stay smaller than certain limits. If we like to obtain results faster the calculation has to be stopped earlier.

We developed another way to find the solution. Our fast algorithm gives result for distribution of liquid crystal in ~0.2 second after changes of any one LC parameter. Some time is necessary for calculation of optical characteristics. For calculation of LC structure we use 100 point that gives accurate reproduction of liquid crystal profiles. The number of point for liquid crystal structure fragmentation is not limits, but 1000 points are enough for any known type of calculation and any applied voltages. It is the maximum step size in our program. The time required for calculation of LC profile with the maximum number of points is around ~0.5 second.

For engineering calculations, it is very important how many parameters are included in the calculations. We include maximal number of parameters of liquid crystal, conditions for liquid crystal on boundary, chirality of liquid crystal mixture.

The profile deformation can be calculated for any initial symmetrical boundary conditions, different twist angle, pretilt angle and anchoring coefficient. After calculation of the profile of LC structure, the program calculates the transmittance or reflectance of the LC cell with two or one polarizers. At the same time it calculates transmittance or reflectance spectrum and color coordinates. All parameters in the program can be changed and all results are shown on the screen in real time.

For investigation of dynamic properties, we included routines for the calculation of relaxation time of the liquid crystal. The result of the calculation shows how the LC cell transmittance (or reflectance) changes with time after the change of applied voltage (TVC). Time delay and relaxation time are shown in the output window on the screen.

An example of a working window is show in Fig.1. On the screen we can see the table of parameters of liquid crystal, alignment layer and parameters of cell configuration. To perform calculation the user selects parameter which he likes to change by clicking on radio button and moves scrolling line on the screen. He sees the result of calculation immediately in four graphical windows. The color of background or letters ‘CDR HKUST’ of the top right window follows the interference color of the current color-coordinate.

.

 ISSN/007-0966X/07/3801-0702-$1.00

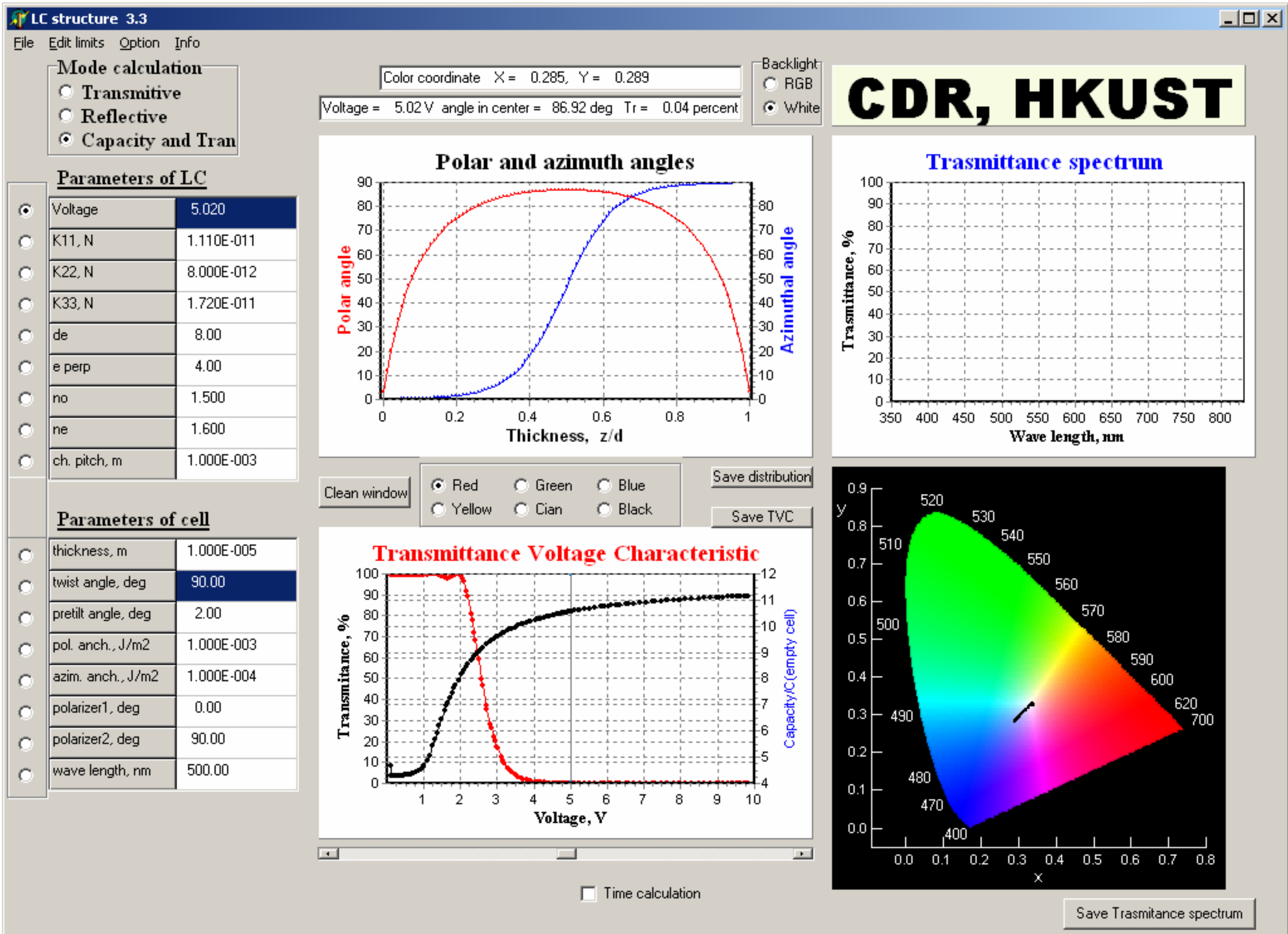

Figure 1. Image of screen in time work program.

Good software design is measured by the number of operations (mouse button clicks) a user must do to obtain the result, when changing any parameters in LC cell. In existing software with the same aim it is necessary to open two or more windows, go to menu and select type of calculation, change parameters and etc. Usually more than 10 clicks are necessary. If the user wants to repeat the calculations several times the number of clicks must be multiplied on number of calculated points.

In our program the user selects a parameter (the first click) and moves scrolling cursor from one value to other (the second click). The result is shown on display immediately. Continuous drag of scrolling bar results in real-time or video-like behavior of the output curves in the graphical windows. If he likes to change other parameter only one more click is required.

3. Example I : Relaxation time of LC cell

Here we show an example of optimization of the response time of a TN display.

Step 1. Determination of LC display thickness, (select cell gap option, move cursor on scrolling bar and control a transmittance spectrum in graphical window “Transmittance spectrum” (Fig.1) and look for values which correspond the second minimum)

Step 2. Change chiral pitch of LC. (select chiral pitch option, change (type in) pitch from infinite to double thickness of the cell and select values of chiral pitch corresponding to minimal response time)

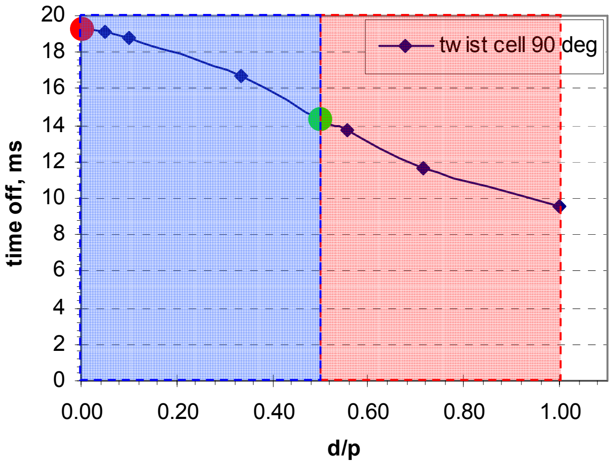

Figure 2. Change time off twist cell from chirality LC

Step 3. Change twist angle of the cell (select twist angle option, change twist angle and select values with minimal response time and maximal transmittance)

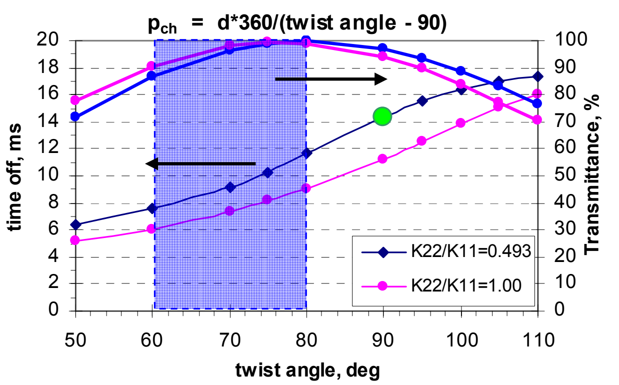

Figure 3. Transmittance and time off of LC cell for maximal value of the relation d/p in dependence on twist angle.

From the abover results, one can decide on the doping concentration and the twist angle of the TN LCD to minimize the relaxation time. A minimal number of manipulations is needed to give a way how to increase the switching speed of LC display .. The same procedure can be repeated for other parameters.

4. Example II: Determination of liquid crystal parameters

For any calculation of liquid crystal structure we must know all parameters of this liquid crystal. Many LC mixtures are available from different chemical companies but it is not possible to find all parameters for all mixtures. Besides any customer can mix two or more components of liquid crystal and form a new mixture. In this situation the parameters of the new mixture is unknown. This situation significantly limits the effectiveness of application of simulation programs to the real liquid crystal devices design.

One can measure the transmittance voltage curve (TVC) and the capacity voltage curve (CVC) to determine the LC parameters. The TVC and CVC are determined by the parameters of the liquid crystal. In principal, there exists a possibility to solve the inverse problem and determine the liquid crystal parameters. From that point view capacity voltage dependence is more interesting. The analysis of this dependence gives possibility to find two component of dielectric permittivity (perpendicular and parallel), and elastic constant (K11 and K33 for parallel cell and K22 for additional twist cell). If the capacity dependence was register with high accuracy it gives possibility to find the pretilt angle in LC cell as well.

For the inverse problem with multi-parametric model to determine the parameters of the system a very large number of calculations of different LC structures is required. It can be done only in the case when the time of calculation of single LC configuration has reasonable duration. Our program calculates one configuration for the time much smaller than 1 second (especially when the graphical interface is turned off). Thus our program is able to solve the inverse problem within approximately 1 min of computation time only! (using an average PC). An example of the capacity voltage dependence is shown on Fig. 4. In this program there exists a special button that starts the fitting procedure for determination liquid crystal parameters. For fitting, this procedure uses two CVC dependences: for the cell with antiparallel LC alignment and the 90 degree twist cell.

.

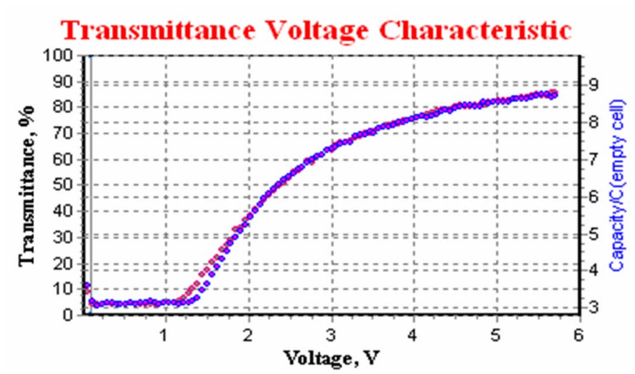

Figure 4. Example of capacity voltage dependence for antiparallel (red points) and twist cells (blue points). (Image of the window for voltage characteristic Fig.1)

For the purpose of CVC measurement, we developed a circuit board that works in conjunction with our program. In our program, we added some more code to realize the measurement device on base of computer board PCI6251 from National Instruments. Two channels measurement device was realized with the simple electrical scheme (Fig. 5)

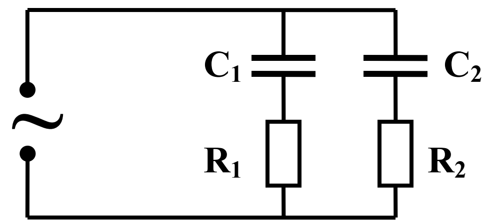

Figure 5. Principal electrical scheme for LC cells capacity measurement.

The computer board generates a signal of arbitrary amplitude. At the same time the voltage levels from resistor R_1 and R_2 are sampled by analog inputs of the board. The output and input signals' clocks are synchronized inside the board. And there is no problem to calculate the capacity of liquid crystal cells C_1 and C_2. When measurement is finished data is saved on disk and is transferred to the program for calculation of liquid crystal parameters.

In fact, after the cells are attached to the voltage outputs the program may operate fully in automatic mode. As soon as capacity measurements are done, the unknown LC parameters are displayed in 1 minute after multi-parameter data fitting.

6. Conclusion

A real-time software, developed by us, gives the possibility to significantly increase the efficiency of LC structure calculations by decreasing the processing time of such calculations. We have also developed a CVC measurement system. The combination of rapid LC structure calculation with the measurement system gives the possibility to obtain the unknown parameters of any LC mixture, which are needed to further optimize the liquid crystal device.

Acknowledgements

This research was supported by the Hong Kong Government Innovations and Technology Commission.

References

[1] V.G. Chigrinov, *Liquid Crystal Devices: Physics and Applications*, Artech House, Boston–London, 1999.

[2] H. Wohler, and M.E. Becker, *Opto-Electronics review*, Vol. **10**, 23, 2002.

[3] V. G. Chigrinov, H.S. Kwok, G.V. Simonenko, D.A. Yakovlev, V.I. Tsoy, *SID 04 Digest*, pp. 982-985, 2004.

[4] V. G. Chigrinov, H.S. Kwok, D.A. Yakovlev, G.V. Simonenko, Yu.Podyachev, *ASID'00 Digest*, pp.244-247, 2000.